7th Framework Programme of the European Union
Clean Sky Joint Undertaking
Green and Sustainable Engine Integrated Technology Demonstrator
SP1-JTI-CS-2011-01

HITECAST PROJECT FINAL REPORT

(from: 01.02.2012 to: 31.01.2014)

entitled:

High temperature Ni-based super alloy casting process advancement

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WARSAW 2014

CONTENT

1. ABSTRACT

The aim of the HITECAST project is to establish castability and weldability limits of Alloy B which is an enabler material for manufacturing a lightweight turbine exhaust components with higher work temperature in comparison with the currently fabricated based on IN718 alloy. The 24-months project is structured in 5 technical work packages and one addressing management and coordination. The consortium consists of jet engines manufacturer (WSKRZ) and two technical universities (WUT and RUT).

Present report concerns detailed description of obtained deliverables and milestones in context of:

1. Development of numerical simulator of casting process (based on the ProCast® software) to support the experimental activities and interpretation of the experimental results.
2. Experimental studies of castability limit parameters of Alloy B.
3. Development of the casting process and challenging the minimum wall thickness below 2 mm.
4. Studies of macro, microstructure and mechanical properties of as cast Alloy B.
5. Optimizing of the welding process parameters of the cast parts made from Alloy B.
6. Demonstration of the capacity efficienty of the developed technology for casting turbine exhaust demo parts.

Based on obtained results it can be concluded that all objectives, deliverables and milestones predicted in the Annex 1 of GA nr 296250 during 24 months of HITECAST project duration have been fulfilled.

2. MANAGEMENT AND COORDINATION ACTIVITIES OF HITECAST PROJECT – (WP6 ACTIVITIES)

The main objective of the WP6 was to provide overall management of the project and to ensure project level quality activities are conducted. It covers all activities of co-ordination and management of the entire project (project control, planning, risk management, meetings, reporting, quality control, dissemination and exploitation and financial audits). The management strategy follows four key components:

1. Management of project activities including technical risks through a clear control and decision-making process through a suitable organizational structure which guarantees that the program goal will be achieved.

2. Management of overall business environment through complementary exploitation studies to ensure a rapid usage of project findings and results.

3. Use of the gained scientific and technological knowledge through a constant networking of all the partners involved and the respective scientific and technical community.

4. Management of gained knowledge property rights based on each partner contribution e.g. by an effective exploitation and implementation strategy.

In figure 1 an overall diagram of the project work plan structure and contents is shown.

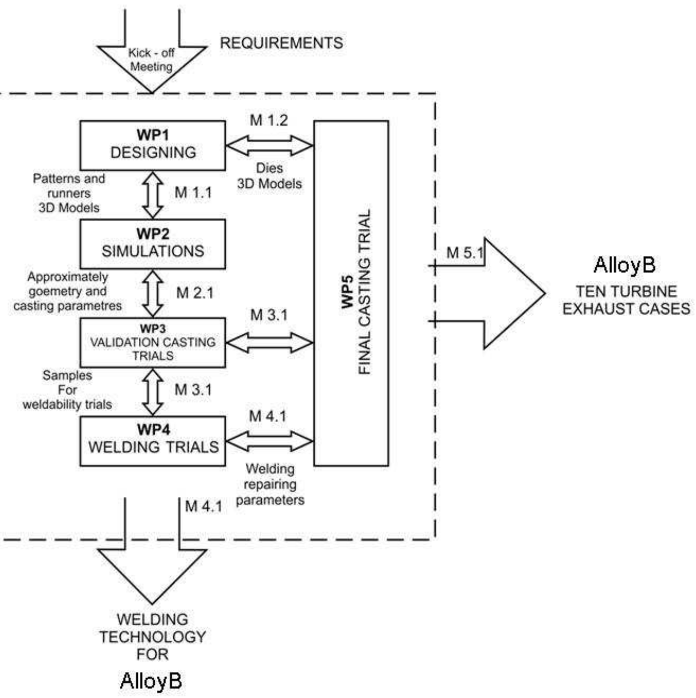

Fig. 1. Pert diagram showing the various WP's and their interdependencies; MS X indicates a Milestone in the project

The timing of WPs is shown in table 1 according to the Annex 1 of Grant Agreement nr 296250 Article 3 "start date" of the project is 01.02.2012 and end of project is 31.01.2014. All activities predicted in project schedule were realized without delay.

Table. 1. Gantt Chart for full duration of the project (1-24months)

		Year 1												Year 2												
WP No	**WP Title**	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	1	10	11	12
WP1	Computational designing elements of wax assembles and dies	■	■	■	■	■	■																			
WP2	Casting process modeling via ProCast software		■	■	■	■	■	■	■	■	■	■	■	■												
WP3	Casting trials – validation and optimization of results of ProCast simulations				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
WP4	Weldability tests							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP5	Final casting trials									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
WP6	Management and quality control	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

The Hitecast project is organized in five technical work packages. Each work package is placed under the responsibility of a work package leader. To reach an adequate and efficient control of the project, the management structure relies on three levels:

- Project Coordinator (PC) – Hubert Matysiak (WUT)

- Scientific Chairman (SC) – Malgorzata Lewandowska (WUT)

- Review Board (RB) – Michel Goulain (CSJU), Robert Lundberg (GKN) and Tadeusz Gancarczyk (WSKRZ)

- Work Package Leaders (WPL)- Krzysztof Kubiak (WP1 and 2), Hubert Matysiak (WP3 and 6), Stanislaw Dudek (WP4) and Rafal Cygan (WP 5).

An overview of the overall project management and WP structure is shown in figure 2.

Fig. 2. Overview management structure

Continuous project management was performed by the Project Coordinator (PC), who:

- organizes and coordinates the work between the different work packages and tasks, to achieve the overall technical consistency of the project,
- takes the lead of this project,
- controls the budget, deliverables and milestones,
- collects all technical, financial and administrative information from all the partners in order to monitor in real time the progress of the project and the global partners involvement (from both technical and financial aspects),
- organizes with the work packages leader the preparation and the production of deliverables and the exchange of information inside the Consortium,
- consolidates the progress reports,

- solves any technical, financial, administrative or contractual issues or conflict between partners, when needed,
- proposes solutions to critical situations (delays etc.) and implements them in agreement with the project participants,
- was the only official channel between the Consortium and the CSJU Officer and Topic Manager Institution,

The Coordinator was responsible in front of the CSJU Officer and Topic Manager Institution for the following:

- progress and annual reports in writing referring to all agreed work packages, technical achievement, time schedule, potential risks and proposal for risk mitigation,
- annual cost statements,
- invitations/organization of contractors meetings and teleconferences,
- preparation and distribution of schedules and meeting minutes for these meetings,

All Contractors actively participated in the review process together with CSJU Officer and Topic Manager Corporation representatives.

The Scientific Chairman and the Project Coordinator together made decisions regarding all technical issues. The Scientific Chairman was responsible for every technical question.

The Review Board role was to review project technical progress. It was constituted by the Topic Manager Representative, CSJU Officer and WSKRZ expert not involved in the project. The Review Board controlled data and results of the project and approved solutions proposed by the coordinator and the work package leaders.

Each work package leader:

- proposed a specific workscope with a detailed planning, including due dates for contractual and internal deliverables, reports and technical progress,

- coordinated the work performed within the work package,
- monitored the work progress and reports regularly to the coordinator about the WP status,
- proposed solution in case of problems within the work package,
- validated and ensured the delivery, in due time, of deliverables for approval by the Scientific Chairman and the Project Coordinator.

2.1. Meetings and teleconferences

The first HITECAST meeting (KICK OFF MEETING) took place in Rzeszow on 22nd and 23rd of November, 2011. The main objectives of the meeting were:

- to provide an overview of the work which will be undertaken in each Work Package
- to determine key priorities for the first three months of the project
- to set the action plan for the next three months period

Agenda of meeting was divided for two sessions – general session and technical session. During general session presentations listed below were given:

- Partners presentations – All presentations covered information about: partners' profile, structure, interest, useful equipment, role and expectations from the project partners.
- Intro of the Clean Sky by Robert Lundberg (GKN) on behalf of Michel Goulain (CSJU) – presentation covered information about: overall structure of Clean Sky and rules and legislation included in Grant Agreement of Hitecast project
- Hitecast project presentation by PC – presentation covered general information about Hitecast project (technical "state of the art", aims, objectives, deliverables, milestones, work packages list, WP's interaction and timing, consortium and management structure, role of partners, budget structure, reviewing and reporting schedule)

- Overview of WP6 (Management and quality control) by PC - presentation covered general information about: objectives; deliverables; management structure; grant agreement and other agreements rules and legislations; responsibilities of coordinator, decision bodies and WP leaders; reporting schedule and procedures; financial rules and statements; confidentiality and disseminations of results procedures.

During technical session overview presentation was given for each RTD work package. Presentations included information about: description of work, aims, objectives, deliverables, milestones, work package timing, risk assessment and contingency plans, role of partners, useful equipment, needed input, plan for next 3 months and expected output. Each presentation was a background for technical discussion, making "decision list" and preparation action plan for first 3 months of project duration.

Four technical meetings were organized. The first took place in Rzeszow on 12-13 of June, 2012, the second took place in Warsaw on 04-05 of December, 2012, the third in Trollhattan on 13-14.06.2013 and last one in Warsaw on 12-13 of December, 2013. The main objectives of the meetings were:

- To provide an current status of the work which was undertaken in each Work Package
- To determine key priorities for the next three months of the project
- To set the action plan for the next three months period

During meeting sessions current presentations were given for each RTD work packages. Presentations included information about: description of work, aims, objectives, deliverables, milestones reporting periods, work package timing, results with discussion, plans for next 3 months and expected output. Each presentation was a background for technical discussion, making "decisions list" and preparation action plan for next 3 months.

Usually once a month a teleconference is organized between the partners and Topic Manager Institution to provide a transfer of knowledge and results. During project duration 28 teleconferences were organized. On each teleconference a discussion about:

- synthesis of activities,
- deliverables, objectives, milestones reviews and recommendations status
- follow-up and update of the time schedule
- main risks and critical issues analysis

are performed.

After each teleconferences and meetings coordinator prepared minutes and technical reports consisting action items by date for next period and current status of running actions and distributed to consortium and Topic Manager Institution Members.

2.2 e-room and project logo

All deliverables and milestones achieved during project realization posses status “confidentional”. Thus we do not present results in public domains without approval Topic Manager Institution . However was created e-room of Hitecast project. Team place was very useful for data storage and exchange in encrypted form. Access to e-room posses only consortium members and Topic manager Institution. Main page of e-room and project logo are shown in fig 3.

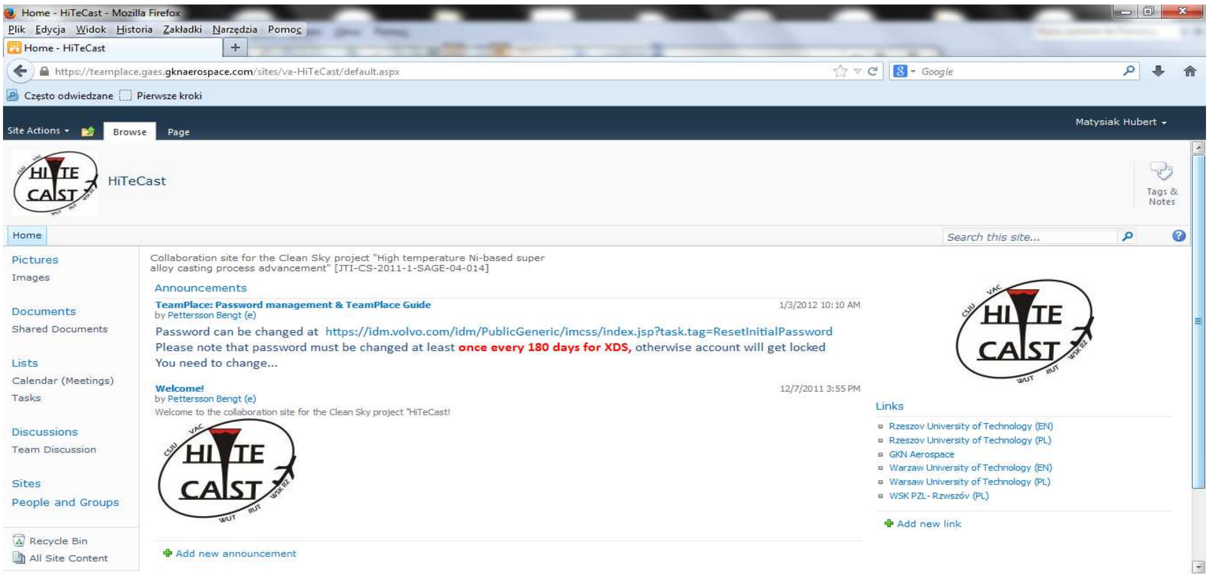

Fig. 3. e-room of Hitecast project

2.3 Deliverables and Milestones review

During project realization a number of deliverables were determined. The established deliverables and milestones will be described and its significance influence will be related to project goal realization. List of defined deliverables and milestones and its current status are listed in tables 2 and 3.

Table. 2. Deliverables of HITECAST project with delivery date

Del. no.	Deliverable Title	WP no./lead beneficiary	Nature	Dissemination level	Delivery date from AnnexI	Actual/forecast delivery date	Status	Comments
D1.1	Report containing 3D models of patterns, runners, wax assembles and dies	1/RUT	R	CO	6	29.08.2012	submitted	Deliverable/Milestone report no. (*VOLS:10166734-000-01, 2012.)* submitted on time and approved by Topic Manager Institution
D2.1	Report containing results of computational simulations of casting process	2/RUT	R	CO	12	13.02.2013	submitted	Deliverable/Milestone report no. (*VOLS: 10178499-000-01, 2013.)* submitted on time and approved by Topic Manager Institution
D3.1	Report containing results of castability trials and specimens characterization	3/WUT	R	CO	18	31.07.2013	submitted	Deliverable/Milestone report no. (*VOLS:10186123-000-01, p176)* submitted on time and approved by Topic Manager Institution
D4.1	Report containing results of weldability trials and specimens characterization	4/WSKRZ	R	CO	24	31.01.2014	No submitted	Deliverable/Milestone report no. (*VOLS: 10178613-000-01, 2014)* submitted on time and approved by Topic Manager Institution
D5.1	Ten turbine exhaust case elements with required technological quality cast, inspected and reported	5/WSKRZ	D	CO	24	31.01.2014	No submitted	Deliverable/Milestone report. no (*VOLS: 10178614-000-01)* submitted on time and approved by Topic Manager Institution
D6.1	12-months progress, management and cost statement report	6/WUT	R	CO	12	18.03.2013	submitted	Annular Hitecast project report no. (*VOLS: 10178615-000-01, 2013)* submitted on time and approved by Topic Manager Institution
D6.2	24 months - Final report	6/WUT	R	CO	24	31,01,2014	No submitted	Final Hitecast project report no. *(VOLS:10192978-000-01)* submitted on time and approved by Topic Manager Institution

Table. 3. Milestones of HITECAST project with delivery date

Milestone no.	Milestone name	WP no./lead beneficiary	Delivery date form Annex I	Achieved	Actual/Forecast achievement date	Comments
MS1	Design of 3D models for patterns, runners, wax assembles and dies	WP1/RUT	6	yes	29.08.2012	Deliverable/Milestone report (*VOLS:10166734-000-01, 2012)* submitted on time and approved by Topic Manager Institution
MS2	Simulations of casting process aiming to guide the experimental trials and interpretation of results	WP2/RUT	12	yes	13.08.2013	Deliverable/Milestone report (*VOLS: 10178499-000-01, 2013)* submitted on time and approved by Topic Manager Institution
MS3	Optimization of casting process: Final solutions for assembler and technological parameters defined	WP3/WUT	18	no	31.07.2013	Deliverable/Milestone report (*VOLS:10186123-000-01, p176)* submitted on time and approved by Topic Manager Institution
MS4	Optimization of welding process	WP4/WSKRZ	24	no	31.01.2014	Deliverable/Milestone report ((*VOLS: 10178613-000-01, 2014),)* submitted on time and approved by Topic Manager Institution
MS5	Ten demo parts successful cast	WP5/WSKRZ	24	no	31.01.2014	Deliverable/Milestone report (*VOLS: 10178614-000-01, 2014.)* submitted on time and approved by Topic Manager Institution

3. RESULTS DESCRIPTION

3.1. WP1 - Computational designing elements of wax assembles and dies [1]

The main goals and objectives of the WP1 were designing 3D models of:

- “simple shape” samples, wedge like geometry with different wall thickness, for investigations: castability and weldability,
- Archimedean spiral assembly for fluidity tests
- samples for chemical composition measurements and mechanical tests (tensile stress rupture and for tests in Gleeble simulator),
- demo part gating systems elements for all wax assembles,
- dies for wax injection technique.

Based on technical documentation (drawings) supplied by GKN Sweden, 3D computational models of demo part was designed. All geometrical requirements were taken into consideration. According to specific geometry of final product, was necessary to design dedicated, thin-walled wedge like geometry samples, for castability and weldability trails and samples to carry out an investigation of microstructure and mechanical properties of castings. Parallel to designing wax assembles for each samples geometry and HUB, 3D models of dies for wax injection technique were designed. All 3D models were designed in ProCast® Software. Final stage of work was fabrication wax patterns and elements of gating systems by Rapid Prototyping technique for verification quality of wax assembles in context its utilization during realization of WP2-WP5.

Based on obtained results all deliverables and milestones predicted in the Annex 1 of GA nr 296250 for of WP1 (scheduled 01.02.2012 – 31.07.2012) have been fulfilled.

[1] Deliverable/Milestone Report of WP1: “Computational Designing Elements of Wax Assemblies and Dies” (HITECAST :JTI-CS-2011-01-SAGE-04-014), (Full report), VOLS:10166734-000-01, 2012, 40 p.

3.2. WP2 Casting process modeling via ProCast software [2]

The main goals and objectives of the WP2 were:

- O2.1. Preparation of thermal properties data base for materials used in the numerical modeling casting process (alloy, shell moulds and shell raping insulator material)

- O2.2. Castability numerical modeling via ProCast software as function of: metal capacity, metal chemical composition, melting, casting and shell temperature, geometry of runners system, thickness of cast section, pouring profile, shell mould material, number of shell coats, filtering system
- O2.3. Modeling of polycrystalline structure of castings

The results of Work Package 2 of HITECAST include numerical simulations of pouring and solidification process for elements designed in WP1:

- Wedge geometry – pouring, solidification and volumetric part of the solid phase in time; grain microstructure simulation with statistical investigation of an average grain area and their diameter,
- Archimedean spiral assembly – pouring and solidification in time
- Numerical simulation comparison of pouring and solidification for Alloy B and Inconel 718 alloys;
- Demo part– pouring, solidification and shrinkage porosity investigation in the volume of the component; two different gating system investigation,

Based on obtained results it can be concluded that all objectives and goals predicted in the Annex 1 of GA nr 296250 for WP2 (scheduled 01.02.2012 – 28.02.2013) have been fulfilled.

<u>References:</u>

[2] Deliverable/Milestone Report of WP2:

*"*Casting process modelling via ProCast software *(Full Report)" (HITECAST :JTI-CS-2011-01-SAGE-04-014), VOLS: 10178499-000-01, 2013, p.69. – submitted and approved by Topic Manager Institution*

3.3. WP3 - Casting trials – validation and optimization of results of ProCast simulations [3]

The main goals and objectives of the WP3 were:

- Optimization of wax patterns and wax assembles geometry
- Optimization of shell mould systems
- Optimization of investment casting parameters for Alloy B
- Establishment and improvement of castability for Alloy B – defining critical wall thickness of casts

The aim of this task was validation and optimization of the input from WP1 and WP2 through casting trials in industrial EX and semi-industrial EX/DX furnaces. During all casting trails only EX processes has been provide. Semi-industrial EX/SX furnace was equipped in “shell heater” with temperature controllers useful for changing and controlling shell mould temperature during pouring and solidification processes which is not allowed in standard EX industrial furnaces. Thermally controlled pouring and solidification was important for optimization of shell temperature, melting temperature and cooling rate for EX casting process of thin-walled parts manufactured from Alloy B alloy.

Feasible solutions of assembly geometry and investment casting process parameters obtained from WP2 (like: metal capacity, metal chemical composition, melting, casting and shell temperature, thickness of cast section, pouring profile, shell mould material, number of shell coats, filtering system) were validated. Ultimately, the most optimal solution was achieved. Task was executed in several steps, as follows. Wax assembles for samples were manufactured utilizing Rapid Prototyping Technique (RUT) and wax injection technique (WSKRZ). Several geometries of samples were manufactured as is shown in attached Figure 4.

(a) (b) (c) (d)

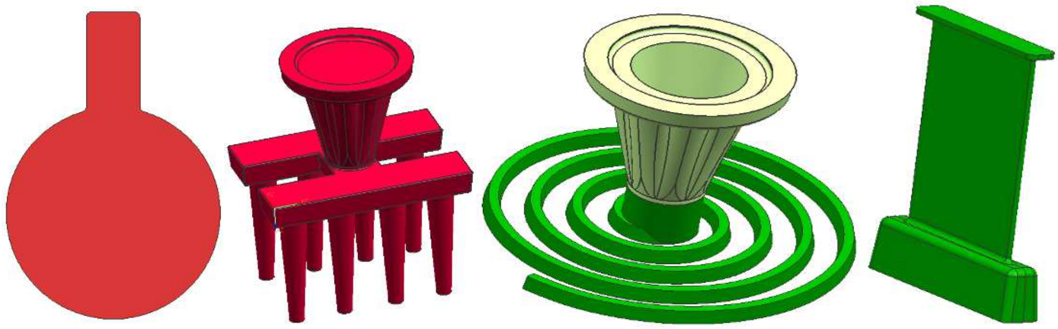

Fig. 4.Samples for investigations

Samples A and B are standard samples for investigations of chemical composition, and mechanical properties. Sample D is a typical for fluidity characterization of cast alloys. Geometry of sample D consist of bulk root and thin-walled airfoil (with thickness gradation) is dedicated for macro and microstructure investigations, controlling susceptibility to missruns formation and castability as well.

Manufactured wax assembles were provided to WSKRZ and RUT investment foundry units for shell mould manufacturing. At RUT castings trials one shell system (no. 1) were implemented, based on alumina and mullite fillers (developed by WUT). Shell primecoat consists of alumina flours and colloidal silica binder – Ludox AM. Alumina grit was applied as a primary stucco. Ten coats mould backup was manufactured by use of ceramic slurries based on mullite filler and colloidal silica binder - LudoxAM. Mullite grits were applied as back-up stuccos. Two different shell mould systems were used during WSKRZ casting trials. In shells from system no. 2 primecoat consists of zircon filler and colloidal silica binder. Alumina grit was applied as a primary stucco. In shells from system no. 3 primecoat was modified by adding 5%wt. of cobalt aluminate $CoAl_2O_4$ inoculant powder. Six coats mould backup was manufactured by use of ceramic slurries based on alumina silicates powders and colloidal silica binder in both cases. Following the shells were de-waxed, burned out, wrapped by insulating material and fired.

Casting trials and samples investigations procedure were scheduled as follow:

1. Differential thermal analysis (DTA) of Alloy B alloy.
2. Casting trials:
    a) Fluidity tests for Alloy B and IN 718 alloys – Archimedean spiral geometry of pattern

b) Castability trials – "wedge" geometry of pattern".
    i. Quality inspections of castings (visual, FPI and X-rays, chemical composition) made from Alloy B and IN 718 alloys.
    ii. Macrostructure investigations as cast state Alloy B and IN 718 alloys.
    iii. Microstructure investigations as cast state Alloy B.
    iv. Hardness and microhardness measurements as cast state Alloy B.
    v. Tensile and stress rupture tests for as cast Alloy B.
c) Casting trials for mechanical tests samples.
d) Casting trials for Gleeble samples for Alloy B.

3. Heat treatment of cast Alloy B alloy
    a) Microstructural characterization of cast and heat treated Alloy B alloy
    b) Mechanical tests: tensile, stress rupture and hardness for cast and heat treated Alloy B alloy
    c) Fractography and microstructural characterization of cast and heat treated Alloy B alloy after tensile and stress rupture tests.

Casting processes were done simultaneously using two furnaces (industrial EX-WSKRZ and semi-industrial EX/DXRUT). Use of two furnaces decreased the overall time needed to execute a designed number of casts. As a primary material for casting trials and investigations Alloy B was used. IN 718 superalloy was used during "fluidity and castability" casting trials as reference material. Casting trials for Alloy B were iterative (and supported by ProCast modeling – WP2 and differential thermal analysis (DTA) investigations) until proper cast samples with homogeneous macro and micro structure and required mechanical properties was fabricated.

The quality of castings was inspected utilizing several techniques, such as: NDT (visual, FPI, X-rays inspections), macro-, microstructure and chemical composition studies (LM, SEM, TEM, XRF, EDS, WDS, AES, EELS) and mechanical tests: hardness, microhardness, tensile and stress rupture. Finally, authors obtain:

- optimal solution for geometry of wax assemblies and shell moulds,
- optimal solution for investment casting process parameters,

- limits for the minimum wall thickness of castings with required properties,
- full macro and microstructure characteristic of as cast Alloy B superalloy,
- mechanical properties of as cast Alloy B for wide range of stress and temperature loading.

In the next step as cast samples were heat treated. The multistage HT consisting of HIP/homogenization, solution annealing, solution treating and age hardening have been applied. Microstructure of heat treaded samples were detailed characterized by LM, SEM, TEM, XRF, EDS, WDS, EELS techniques. Mechanical behavior of HT superalloy was investigated during tensile and stress rupture tests. Failure mechanism has been defined based on detailed fractography and microstructural studies (LM, SEM and TEM techniques were applied). Based on obtained results authors achieved:

- optimal solution for HT process for Alloy B in cast state,
- mechanical properties data base for cast and heat treated Alloy B for wide range of stress and temperature loading,
- full microstructure characteristic of cast and heat treated Alloy B superalloy,
- influence of heat treatment and mechanical test conditions on microstructure and failure mechanism of cast and heat treated Alloy B superalloy.

Additionally, samples for weldability and Gleeble simulator tests (WP4) were cast and heat treated.

Based on obtained results it can be concluded that all objectives, deliverables and milestones predicted in the Annex 1 of GA nr 296250 for WP3 of HITECAST project have been fulfilled.

References:

[3] Deliverable/Milestone Report of WP3:

"Casting trials – validation and optimization of results of ProCast simulations *(Full Report)" (HITECAST :JTI-CS-2011-01-SAGE-04-014), VOLS:10186123-000-01, p176. – submitted and approved by Topic Manager Institution*

3.4. WP4 - Weldability tests [4]

The goal of WP4 is to perform welding test using simple test sample and final welding repair of cast demo parts with required technological quality.

Task was executed in several steps, as follows. Firstly high temperature characteristics of AlloyB was carried out using Gleeble 3800 metallurgical simulator. Based on hot ductility tests several parameters has been determined for cast AlloyB:

- Value of resistance force
- nil strength temperature (NST)
- nil ductility temperature (NDT)
- NST- NDT range
- ductility recovery temperature (DRT)
- strength recovery temperature (SRT)
- Brittleness temperature range BTR
- Ductility Recovery Rate DRR

The hot ductility test results provided insight into material susceptibility to weld cracking such as heat affected zone liquation cracking.

Based on obtained data in next step TIG method repairing welding parameters like: preparation method, type of welding torch, type of torch nozzle, type of shielding method, welding current and filler material were set up. Various geometries from simple shape samples (wedges – fig. 5) to demo part geometry were used. Welded alloy was used in various conditions, such as cast, as solution heat treated and fully hardened.

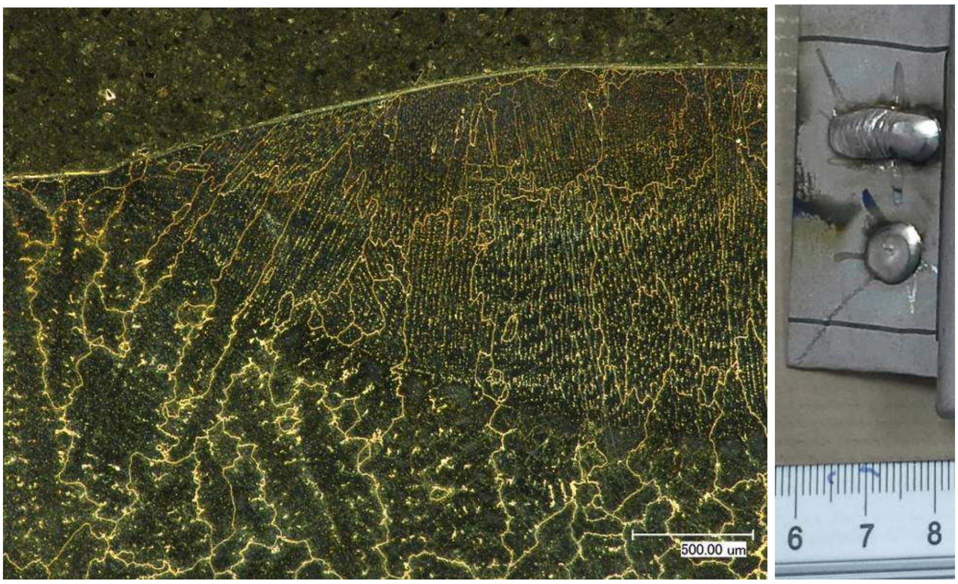

Fig. 5. Example of plug and slot welds on wedge samples geometry

The quality of castings after TIG repairing tests were inspected utilizing several techniques, such as: NDT (FPI, X-rays inspection), microstructure characterization (LM and SEM) and mechanical properties (microhardness). Based on the obtained results can be concluded that welding process parameters for demo parts were successfully validated because obtained after repair samples and parts fulfilled technical requirements.

All objectives, deliverables and milestones predicted in the Annex 1 of GA nr 296250 for WP4 of HITECAST project have been fulfilled.

<u>References:</u>

[4] Deliverable/Milestone Report of WP4:

"Weldability tests (Full Final Report)" (HITECAST :JTI-CS-2011-01-SAGE-04-014), *VOLS: 10178613-000-01, 2014*, 29 p. – submitted and approved by Topic Manager Institution

3.5. WP5 - Final casting trials – summary [5]

The goal of WP5 was to perform final casting of ten demo parts per drawing with required technological quality.

According to results received from WP1, WP2 and WP3, wax assembles (through Rapid Prototyping technique) and shell moulds were manufactured. Based on results of WP3 included optimal solution of casting parameters (melting, pouring and solidification) and limits for the minimum wall thickness of castings induction melting and Investment Casting (VIM IC) process was used for manufacturing of 10 demo parts made of AlloyB and 2 demo parts made of IN 718. Casting trials were supported by computational simulations with using Procast software.

Standard quality control procedures, common in aircraft industry, were applied to assess the quality of castings: FPI, X-Ray inspection, macrostructure characterization dimensions control ("white light measurements") and chemical composition. Additionally microstructure of demo parts were characterized (in as cast state and heat treated) by LM and SEM observations. Based on the obtained results it can be concluded that casting process parameters for demo part were successfully validated as obtained part fulfilled technical requirements.

All objectives, deliverables and milestones predicted in the Annex 1 of GA nr 296250 for WP5 of HITECAST project duration have been fulfilled.

References:

[5] Deliverable/Milestone Report of WP5:

"Final casting trials *(Full Final Report)" (HITECAST :JTI-CS-2011-01-SAGE-04-014), VOLS:* VOLS: 10178614-000-01, 2014, *p. 109. – submitted and approved by Topic Manager Institution*

4. DISSEMINATION AND/OR EXPLOITATION OF PROJECT RESULTS

Dissemination plan and/or exploitation of project results have been fully covered by Consortium Agreement, Implementation Agreement Non Disclosure Agreement signed by whole partners. The general results obtained by the partners within the project have been available by the partners and topic manager institution. However, specific data and technological solutions developed by a consortium are confidential due to competitiveness reasons.

The HITECAST project was focused on development (for new Alloy B) investment casting and repairing welding methods and its parameters to fabrication of lighter of turbine exhaust case components for new jet engines. Lightweight and efficient turbine components have great impact on reduction fuel consumption and emission of nitrous oxide by jet engines. It means major aim of this project is compatible with ACARE SRA 2020 objective - environmentally friendly aircraft engines. For GKN Areospace Engines Systems Sweden (aircraft company - Topic Manager Institution) responsible for "JTI-CS-2011-01-SAGE-04-014 topic call" global solution received in this project like:

- Vacuum induction melting and investment casting process for manufacturing thin–walled components made from Alloy B,
- TIG repairing welding of casts made Alloy B,

have significant business impact (increasing of competitiveness and cost reduction of manufacturing). It means that GKN Areospace Engines Systems Sweden will use the generated foreground in the development of future generation more environmentally friendly aircraft engines and achieved solutions are protected by non disclosure agreement.

Those results (listed below – Table 4) which are not protected by disclosure agreement will be disseminated in different courses of action.

- Numerical model for simulation of solidification process and macrostructure of Alloy B, Procast software with dedicated Alloy B data base.

- Multiscale methodology of microstructure characterization of AlloyB in as cast state and heat treated.
- Multiscale methodology of fracture analysis of AlloyB in as cast state and heat treated.
- Tensile and stress rupture behavior of cast AlloyB during mechanical tests under NADCAP certificate.

In detail, the industrial partner and universities have their own strategy to exploit or disseminate the results of the project. WSKRZ (industrial partner) disseminate the results within all of their business units of the company and transfer the knowledge and experiences gained to other technological applications especially for casting structural components. The universities (WUT and RUT) will present the knowledge at conferences (some results already present at NIMS Conference 2013) and through publications (major results already published see Table 5 and 6). Hitecast project increase also our competences and scientific reputation. Based on results of Hitecast project we established new international consortium and generate and submitted new R&D project entitled Failure analysis and damage mechanisms of newly developed, gamma-prime strengthened Ni - based superalloy (FAMEC SP1-JTI-CS-2013-02, 632468).

Table. 4. Exploitable knowledge and its use

Type of exploitable Foreground *	Description of exploitable foreground	Confidential Yes/no	Foreseen Embargo date Dd/mm/yyyy	Exploitable products or measure	Sector of application	Timetable, commercial or any other use	Patents or other IPR exploitation licences	Owner &other beneficiary(s) involved
R&D	Solidification of Alloy B	no	n/a	Numerical model for simulation of solidification process and macrostructure of Alloy B, Procast software with dedicated Alloy B data base	Aviation, Energy, Metallurgy	2014-2015	No patents or copyrights foreseen at this time	WSKRZ, RUT, GKN
R&D	Microstructure characterization of cast Alloy B	no	n/a	Multiscale methodology of microstructure characterization of Alloy B in as cast state	Aviation, Energy, Metallurgy	2014-2015	No patents or copyrights foreseen at this time	WUT, GKN

				and heat treated				
R&D	Fracture analysis of cast Alloy B	no	n/a	Multiscale methodology of fracture analysis of Alloy B in as cast state and heat treated	Aviation, Energy, Metallurgy	2014-2015	No patents or copyrights foreseen at this time	WUT, RUT GKN
R&D	Tensile and stress rupture of cast Alloy B	no	n/a	Tensile and stress rupture behavior of cast Alloy B during mechanical tests under NADCAP certificate	Aviation, Energy, Metallurgy	2014-2015	No patents or copyrights foreseen at this time	RUT, GKN
R&D	Vacuum induction melting and investment casting of thin–walled components from Alloy B alloy	yes	2020	Procedures of whole Vacuum induction melting and investment casting processes of thin–walled components from Alloy B alloy	Aviation, Energy, Metallurgy	2014-2015	No patents or copyrights foreseen at this time	WSKRZ, RUT, WUT, GKN
R&D	Welding of cast Alloy B	yes	2020	Procedures of whole TIG manual repairing and joining welding of cast Alloy B	Aviation, Energy, Metallurgy	2014-2015	No patents or copyrights foreseen at this time	WSKRZ, RUT, WUT, GKN

Table. 5. List of scientific publications

No	Title	Main author	Title of periodical of the series	Number date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	Is/will open access provided to this publication
1	Microstructure of alloy B superalloy after vacuum induction melting and investment casting of thin–walled components	H. Matysiak et al.	Materials	*Materials* 2013, *6*(11)	MDPI - Open Access Publishing	Switzerland	2013	5016-5037	doi: 10.3390/ma6115016	yes

Table. 6. List of dissemination activities

No.	Type of Activities	Title	Main Leader	Date/period	Place	Type of audience	Size of audience	Countries addressed
1	Conference Warsaw University of Technology, National Institute of Materials Science& Hitachi High Technologies 4th Joint seminar (Satellite Meeting of NIMS Conference)	Microstructure characterization of as cast state newly developed γ'-strengthen Ni based superalloy	WUT	2.07-4.07.2013	NIMS, Tsukuba, Japan	Academic/industry	50	All

6. SUMMARY

Present report concerns description of results and obtained deliverables and milestones in context of:

- designing 3D geometrical models of samples, runners elements, dies and turbine exhaust component for computational simulation and for performing wax assembles elements,
- investment casting process simulations utilizing ProCast software to direct the experimental casting trials and support interpretation of the experimental results for casting IN718 and Alloy B,
- casting trials for validation and optimization of technological parameters for receiving proper castability and microstructure and mechanical properties for Alloy B cast samples,
- welding trials form optimization welding fabrication and weld repair process on Alloy B,
- validation and optimization of casting parameters for fabrication of demo parts approved by aeroengine company.

In view of the obtained results can be concluded that Alloy B is a good candidate for casting and welding of large and thin-walled elements of aerospace turbines exhaust structural components. All objectives, deliverables and milestones predicted in the Annex 1 of GA no 296250 of HITECAST project duration have been fulfilled.